Urban Traffic Congestion Pricing:
Literature Review and Real-world Applications

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Abstract

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Traffic congestion has become one of the most pressing problems for metropolitan cities around the world. Hence, the introduction of congestion pricing is often debated in many larger cities, yet only few have successfully implemented it so far. This thesis reviews the contemporary body of literature over the past decade and real-world applications of urban traffic congestion pricing. Through a systematic literature search and classification process, three overarching themes are identified: 1) the effectiveness of congestion pricing practices; 2) main obstacles including public acceptability and equity concern; and 3) scheme optimization. This study further identifies secondary effects as the neglected area that require more attention in future research. Based on the findings, the study analytically discussed three influential real-world cases: Milan, Gothenburg, and New York City. The high public acceptability of Milan's Area C plan can be explained from its detailed scheme design. The case in Gothenburg is criticized for hasty implementation

and lack of in-depth research and detailed scheme design. New York City has experienced tortuous process before the final approval, and it will still face the challenge of equity concern. Based on the literature review and discussion of real-word applications, this study concludes political support is one determining factor of congestion pricing implementation which is as important as public acceptability. Additionally, the significant influential impacts between cases are identified as one propulsion for future development. Finally, prospects for widespread implementation in developing cities and American cities are explored and assessed as challenging.

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Chapter 1: Introduction

Traffic congestion in densely populated cities creates significant negative externalities, such as travel delays, unreliability, increased fuel consumption, and air pollution. According to the Global Traffic Scorecard (2019), Americans lose on average 99 hours a year to traffic, equivalent to a loss of $1,377 per driver.

Congestion pricing is universally recognized as the most effective transportation demand management method to reduce congestion (Baghestani et al., 2020; Gu et al., 2018; Small & Yan, 2001; van den Berg & Verhoef, 2011; Yang & Huang, 2005). The rationale of congestion pricing stems from basic economic theories. Most traffic congestion costs are caused by travelers together, and individual travelers are unaware of the externalities they impose on others. Thus, individual travelers do not pay the full marginal cost of their travels, resulting a negative externality (de Palma & Lindsey, 2011). Congestion pricing aims to internalize the costs of this negative externality to every traveler. Attracted by the theoretical advantages, in the past many cities discussed and examined the possibilities to introduce congestion pricing, yet only five cities succeeded to-date: Singapore, London, Stockholm, Milan, and Gothenburg.

Over the last decade, both literature and real-world practices have advanced considerably, creating valuable insights. Milan and Gothenburg's congestion pricing plans were introduced in 2012 and 2013, respectively. New York City's congestion pricing plan was first proposed in 2007, and got a breakthrough on April 8, 2021 when the federal government activated the environmental assessment period for this plan, which has been delayed because of the political resistance before then.

Most current literature on congestion pricing concentrate on previous influential cases or focus on specific niche topics (Anas & Lindsey, 2011; Gu et al., 2018; Lehe, 2019). This thesis aims to provide a comprehensive literature review of the last ten years' and critically discuss the latest practices to investigate and present this field thoroughly. The objectives of this research are as follows: 1) reviewing and synthesizing current research to identify critical elements; 2) reviewing existing real-world applications; 3) and providing implications for future congestion pricing implementations.

In chapter 2, I introduce the research methods which consist of two major steps: literature search and literature classification. Then, chapter 3 introduces economic rationale, different types of schemes, and previous urban congestion pricing experience to get an overview of this field. Then, three essential themes emphasized by various scholars and one neglected area are identified and explained in chapter 4. Finally, I outline three latest influential cases in chapter 5 and discuss their implementation, effects, related issues and several implications for future development.

The utility of this work for an academic audience is to quickly grasp the basic knowledge of urban congestion pricing, learn the latest practical experience, and be informed of the current essential topics. With the implications from this thesis, it would be clearer to consider the adoption of congestion pricing in specific backgrounds or figure out valuable topics in academics.

Chapter 2: Research Methodology

2.1 Literature Search and Evaluation

The two main databases used for this systematic literature review are Web of Science and EBSCO. The search parameters used limited results to peer-reviewed journal articles published in English between January 2010 and April 2021.

The initial search terms were "congestion pricing," "congestion charge," and "road pricing." Typically, "congestion charging" and "congestion charge" were often used interchangeably. "Road pricing" refers to a general fee related to the use of a roadway facility (Small, 1997) and not only comprises congestion pricing but also other pricing mechanisms, including toll roads. During the initial search process, it was identified that many papers used "road pricing" but referred to "congestion pricing" (e.g., Beria, 2016; Borjesson et al., 2015; Rouwendal & Verhoef, 2006; Schaller, 2010) or mainly discussed "congestion pricing" together with other road pricing methods (e.g., Anas & Lindsey, 2011). Therefore, "road pricing" was included as one of the keywords. After applying these keywords in the next search, EBSCO showed 1,615 records and Web of Science presented over 40,000 records.

This research focuses on area-based congestion pricing in the urban context, thus the facility-based scheme and distance-based schemes which charge for certain facility use or charge vehicles based on the travel distance respectively were excluded (de Palma & Lindsey, 2011). This research further discusses congestion pricing within the scope of transportation planning. Therefore, specific topics in the engineering field, such as mathematical models and numerical analysis were also excluded. Based on these criteria, the records from EBSCO were narrowed down by subjects and publications and the records from Web of Science were narrowed down by categories and source titles as detailed in Table 1.

Table 1. Literature Search Terms

Database	Types	Search Terms
EBSCO	Subject: Thesaurus Term	congestion pricing, traffic congestion, transportation, traffic flow, public transit, pricing, urban transportation, cities & towns, transportation policy, choice of transportation, roads, government policy, urban planning, transportation demand management, metropolitan areas, sustainability transportation, city traffic, externalities, sustainable development, transportation cost, transportation planning, user charges, public welfare, transportation research
	Publications	transportation research: part a, journal of advanced transportation, transportation research: part b, transportation science, international journal of sustainable transportation, transport policy, transportation research: part c, transport reviews, transport, transportation research: part e, journal of urban planning & development, journal of transport geography, journal of the American planning association, European planning studies, European transport research review, international journal for traffic & transport engineering
Web of Science	Web of Science Categories	transportation, urban studies, regional urban planning
	Source Titles	transportation research: part a, transportation research record, transportation research: part b, transport policy, transport, transportation research: part e, journal of urban economics, ,transportation research: part d, urban studies, research in transportation economics, journal of transport geography, transportation science, case studies on transport policy, international journal of sustainable transportation, journal of transport economics and policy, cities, economics of transportation, transport reviews

After narrowing the results down, EBSCO provided 681 records and Web of Science indicated 1,508 records. Next, relevant papers were sorted and identified by reading the title and abstract. After reviewing the first 300 records of each database and combining the sources, a total of 165 studies were identified, including 28 duplicates. The inclusion criteria were as follows:

I. This study focuses on area-based urban congestion pricing, which comprise zonal and cordon schemes. Therefore, either practices or discussion based on facilities-based and distance-based schemes are excluded in this study.
II. Studies of implemented, rejected, in-progress, or proposed congestion pricing schemes are all included.

III. This study mainly includes literature in the context of transportation planning. Articles that concentrate on specific topics in the engineering field, such as mathematical models and numerical analysis, are also excluded in this study.

IV. In this study, urban congestion pricing is aiming to relieve congestion in city centers. Therefore, several area-based practices or discussion in the airport area are excluded.

Next, articles were skimmed to further evaluate the relevance of the studies. First and foremost, the duplicated articles of the two databases are valued and included in the review. After the review, a total of 25 articles were excluded: 7 were excluded due to a lack of full-text source availability to the public; 12 were excluded because the main content related to methodological aspects of the subject (particularly those that require mathematical analysis); and 6 were excluded because of focusing on congestion pricing technologies. In the end, 112 articles were selected from this literature search for the literature review.

Through the literature review process, 26 articles were identified as supplementary sources through a backward and forward search, with 7 of them meeting all criteria listed above while being neglected through the selection process. A total of 19 articles before 2010 were identified as highly influential in this field or closely related to topics that are discussed in this study. Concluding, 138 articles were included in the final literature review. Figure 1 shows the search and screening process.

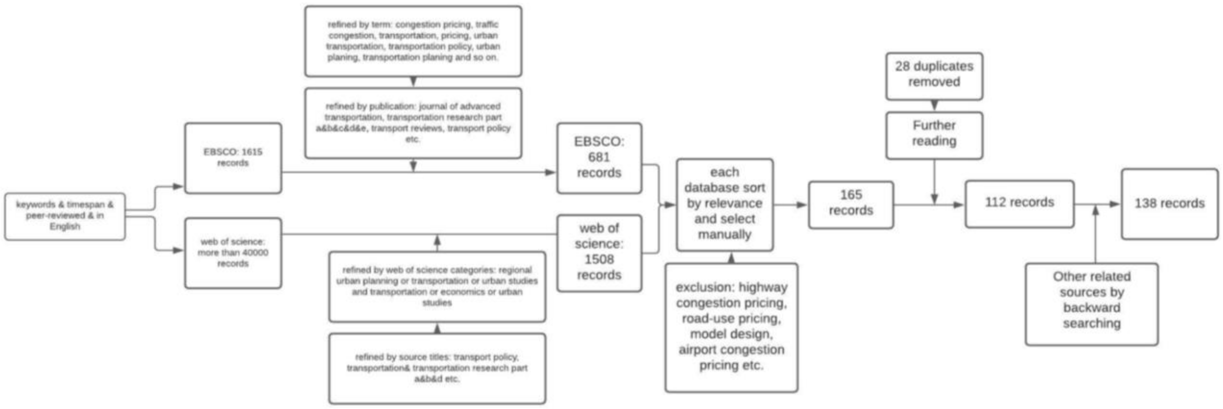

Figure 1. Literature Search and Screening Process

2.2 Classification and Analysis

The literature search categorized 138 studies into different types to identify the topics discussed in the last ten years. Four main themes were identified: 1) public acceptability, 2) effects of practices, 3) scheme optimization, and 4) equity concern.

The most frequently discussed theme of the last ten years' literature is public acceptability. There are 22 articles seeking to investigate factors that influence public acceptability based on existing cases and 5 articles examining the potential public acceptability of specific proposals. The effects of congestion pricing practices is discussed in 23 studies and consists of direct effects and secondary effects. Direct effects refer to the effects in transportation and environment, which are identified as the main purpose of congestion pricing and evaluated in most cases (Anas & Lindsey, 2011; Baghestani et al., 2020; Börjesson & Kristoffersson, 2014, 2015). Secondary effects, such as real estate effects, business effects, health effects, were also explored in these studies. Further, 25 studies investigated congestion pricing optimization through various aspects. Herein, heterogeneity was emphasized as one aspect that could optimize scheme design. Other alternative methods, such as tradable credits, are also debated and verified systematically. Additionally, 10 articles focus on equity concerns. Table 2 shows the contents and numbers of studies for each theme.

Table 2. Main Themes Identified in the Literature Review

Main Themes	**Contents**	**Number of Studies**
Public acceptability (27)	Analyzing Factors influence public acceptability	22
	Examining public acceptability of certain proposal	5
Effects of practices (24)	Direct effects: including transportation and environmental	15
	Secondary effects of congestion pricing	9
Scheme optimization (25)	User heterogeneity	10
	Alternative method: Tradable credits	11
	Other	4
Equity concern (11)	Exploring the equity effects of congestion pricing	11

Other themes that were recognized in lower volumes include lessons from existing cases from the political perspective (7 articles), the application of policy for the development of autonomous vehicles (7 articles), and implementation in a regional context (4 articles). While these less relevant themes are outside of the scope of the current study, all literature pertinent to the main themes are detailed, reviewed, and analyzed.

Chapter 3: Congestion Pricing Overview

In order to quickly establish adequate background knowledge for further analysis, this section explains the economic rationale behind this policy, demonstrates four types of congestion pricing, and summarizes the urban congestion practices before 2010.

3.1 Rationale

The theoretical background of congestion pricing is based on the basic economic principle of marginal-cost pricing (Verhoef et al., 1996). When supply and demand are in balance, an equilibrium exists in market economics. The user equilibrium in road use exists at the intersection of these two curves (see Figure 2), which indicates how high traffic volumes will be and what the related average highway-user costs will be at that volume level. Congestion happens when each successive vehicle imposes on all the others by causing the decrease speed of the entire flow. Therefore, the true opportunity cost of society includes both the costs that individual users suffer as well as the congestion externalities. From the point of view of society, the social equilibrium would occur when marginal social cost meets the demand curve where all highway users value their trips as much as the actual incremental cost to society. However, if negative externalities caused by congestion are not directly reflected in the market price, the opportunity cost to society will be greater than the price that drivers face, thus leading to excessive consumption. Figure 2 shows the traffic flow of user equilibrium being higher than the traffic flow of the social optimum, which indicates that a large number of drivers use the facility at a lower price than the cost to society. Under these circumstances, congestion pricing is introduced to require drivers using congested roads to pay a toll equal to the marginal cost to society in order to keep the traffic volume at a level beneficial to society.

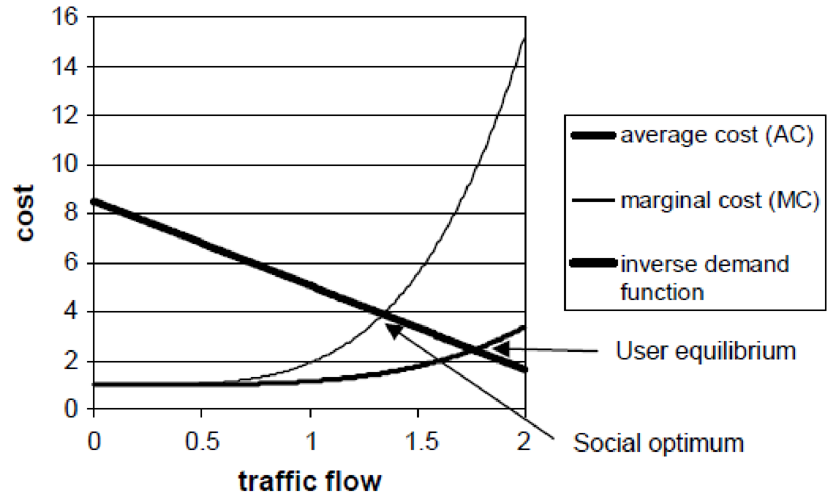

Figure 2. Pigou-Knight Analysis

Note: Rouwendal & Verhoef, 2006.

3.2 Scheme Classification

De Palma and Lindsey (2011) divided congestion practices into four categories, which will be used in this thesis: 1) facility-based schemes, 2) cordon schemes, 3) zonal schemes (i.e., area charge or area license), and 4) distance-based schemes. This classification method has been generally accepted by many scholars as the standard over the past ten years (Anas & Lindsey, 2011; Gu et al., 2018; Lehe, 2019). Notably, the cordon and zonal schemes are designed to relieve the congestion of a certain area and are usually referred to as area-based or zone-based schemes (Gu et al., 2018; Parry, 2009).

<u>Cordon Scheme</u>

A cordon scheme (see Figure 3) indicates drivers pay a toll as they pass several control points which connect to form a cordon or a ring around the city center (De Palma & Lindsey, 2011). This includes either inbound or outbound crossing (or both), but except the travel within the bounded area. Cordon-based schemes have been the most widely implemented congestion pricing form in practice (see Table 3) and have been the subject explored in recent literature (Lehe, 2019).

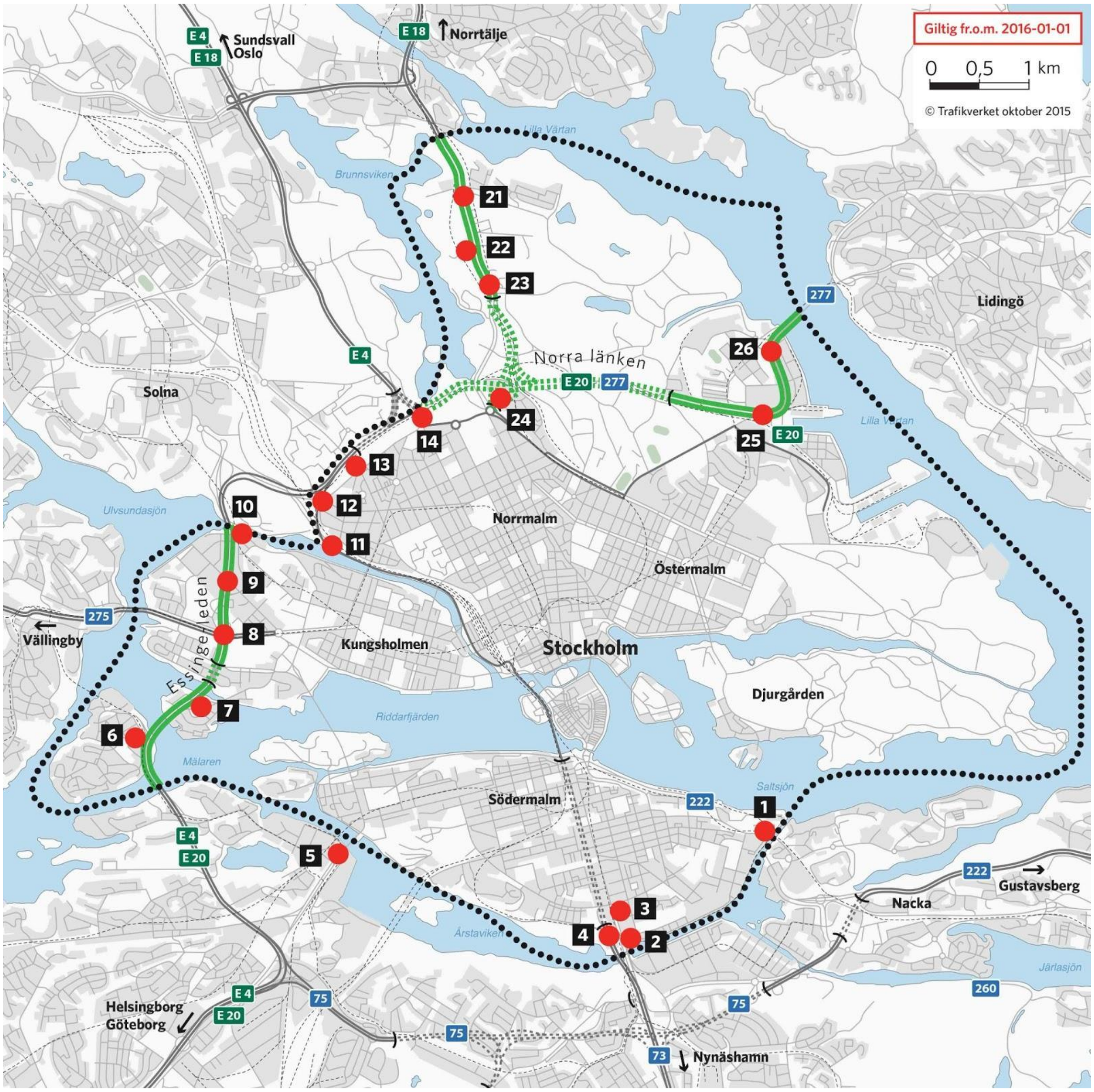

Figure 3. Stockholm Congestion Pricing

Note: Transportstyrelsen (2021).

Zonal Scheme

Zonal schemes (i.e., area charges or area licenses) require drivers to pay the fee to enter or exit the bounded area as well as when traveling within the area. The boundary is usually designed by the government and based on existing geographic features or essential urban paths (Anas & Lindsey, 2011). Though zonal schemes have been researched and discussed in academia, they are rarely applied in practice except for the London Congestion Charge implemented in 2003 (see Figure 4).

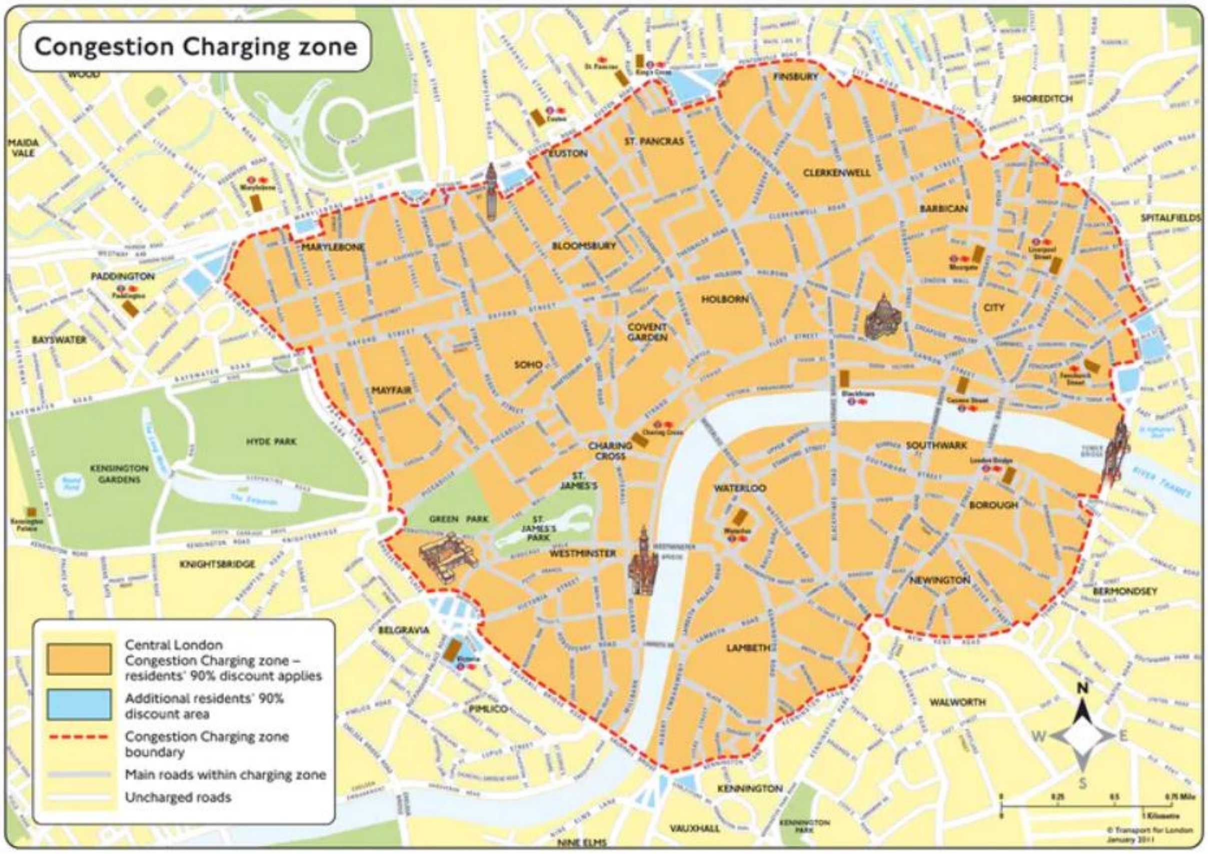

Figure 4. London Congestion Charge Zone

Note: Transport for London (2007).

<u>Facility-based Scheme</u>

Toll, a typical form of road pricing, is commonly imposed to refund and maintain transportation infrastructure. It is usually applied on roads, bridges, and tunnels to charge for facility use. Despite their common use, few of them are designed for congestion reduction(de Palma & Lindsey, 2011). The famous practical facility-based schemes are implemented in the US as High-Occupancy Toll (HOT) lanes, which allow vehicles to pay the extra fee to use high-occupancy vehicle (HOV) lanes (Federal Highway Administration, 2021).

Distance-based Scheme

Distance-based schemes comprise various pricing mechanisms to charge vehicles based on the travel distance linearly or nonlinearly (De Palma & Lindsey, 2011). Most of these schemes are supported by satellite positioning systems or radio service (Liu et al., 2014). This study's scope only includes research related to area-based schemes that operate on a relatively large scale in an urban context. All discussed congestion pricing schemes are categorized in Table 3.

Table 3. Categorized Congestion Pricing Schemes

	Cordon Scheme	**Zonal Scheme**
Implemented	Singapore (EPR & ALS) Stockholm, Sweden Milan, Italy Gothenburg, Sweden	London, UK
Rejected	Hong Kong, China	Edinburgh, U.K. Manchester, U.K.
Being Discussed	New York City, USA San Francisco, USA	Jakarta, Indonesia

3.3 Urban Congestion Pricing Experience

Singapore

The Singapore Area License Scheme (ALS) was the first application of an urban road charge. In 1975, the city state launched a congestion pricing program to alleviate the congestion of the central business district during morning peak hours (Phang & Toh, 2004). The ALS was a cordon-based scheme with a time-dependent charge. In 1998, the ALS was replaced by the current Electronic Road Pricing (EPR) scheme because of the easier and more precise charge administration (Chin, 2010). The ERP scheme is a fully automatic system with gantries detecting in-vehicle electronic smart card units. The tolls vary by time of day, vehicle types, and location. Other than cordon areas, the EPR also includes control points to control traffic on expressways. The ALS scheme reduced congestion greatly (44%) while increasing travel speed, temporally and spatially assigning traffic volume (Phang & Toh, 1997). EPR led to a 15% trip reduction (Menon, 2000). The net revenue from the system is then utilized for the construction and maintenance of roads and improvements of public transportation (Phang & Toh, 2004). Moreover, there are many complementary transportation management methods to the EPR schemes that seek to reduce congestion, such as increasing parking fees and establishing park-and-ride spaces.

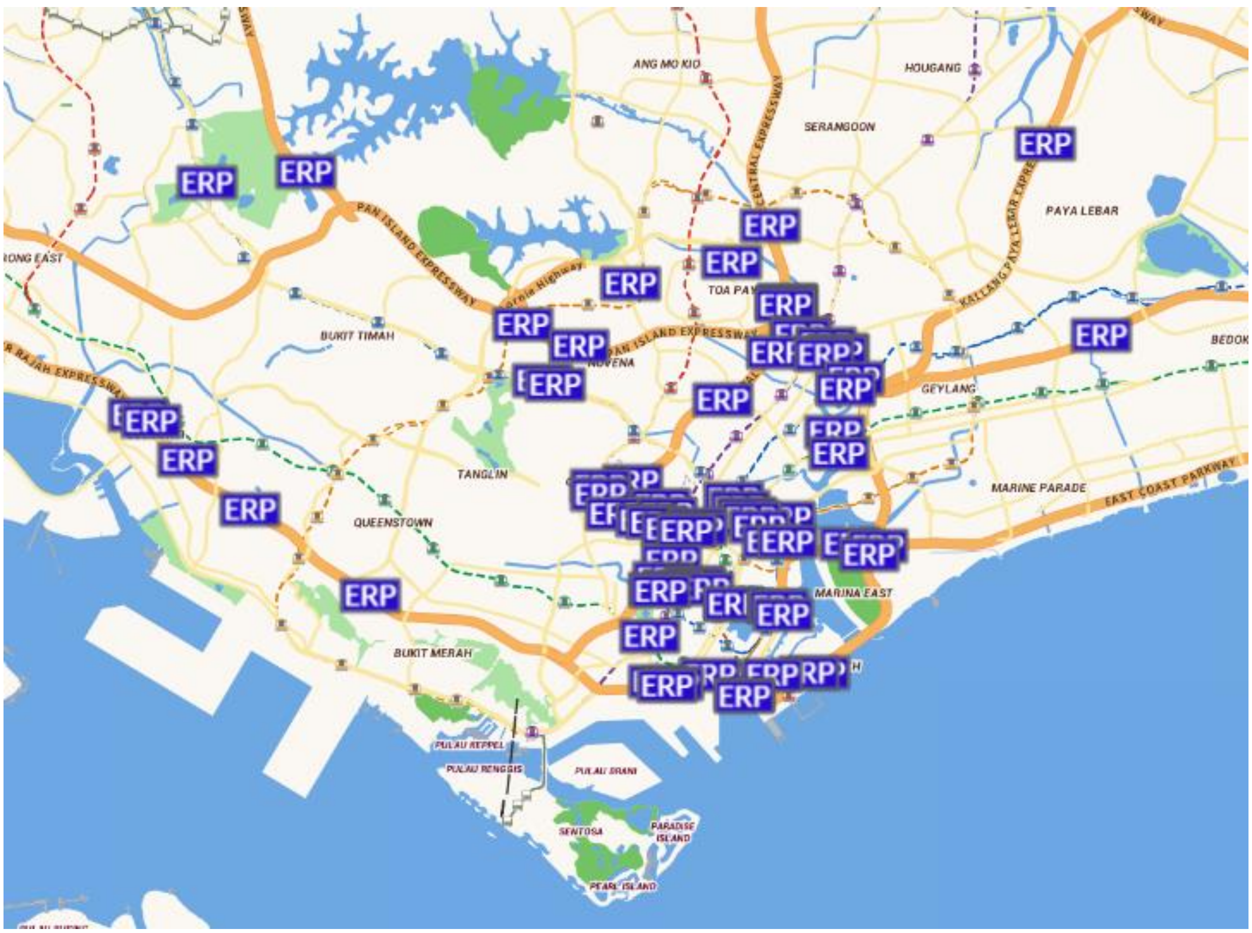

Figure 5. Singapore Electronic Road Pricing

Note: Singapore Government Transportation Agency, 2021.

<u>London</u>

The London Central Charge (LCC) was introduced in 2003. This scheme imposed a daily flat charge to vehicles that travel across the charging zone or within the zone (residents receive a 90% discount) with unlimited travel times. With an emphasis on improving air quality, an Ultra Low Emission Zone discount was applied to the system in 2012 to encourage low-emission vehicles. The effect of congestion reduction has proven to be significant. Car entries fell 33% according to the annual reports of Transport for London from 2003 to 2008. It also greatly boosted bus ridership (Leape, 2006; Santos & Shaffer, 2004). But the recent popularity of ride-hailing apps (e.g., Uber and Lyft) causes congestion again because ride-hailing cars are exempted from the charge (Lehe, 2019). Also, the effect of travel speed is disappointing because the average travel speed has seen no notable increase but instead worsened in recent years (Tang, 2021). Revenues from the charge were reinvested to London's public transport system (Leape, 2006).

Stockholm

Introduced in 2006, Stockholm's congestion pricing scheme is the largest urban pricing case so far. It is a time-variable toll on both directions of weekday travel with a cordon around the central city. The trial was implemented in 2006 and became permanent in 2007 due to positive voting results (Eliasson & Jonsson, 2011). The impact on traffic was significant, as traffic flow fell 28% at first and then stabilized at 20%, which even exceeded the forecasted 16% drop (Börjesson et al., 2012). Further, despite the fast city development, traffic remained constant for more than ten years, which points to the resilience of this traffic policy. Meanwhile, the program also has the significant beneficial effect of pollution reduction, which has long-time health side effects (Eliasson, 2008). Unlike London and Singapore, the revenue is entirely devoted to new road construction and not public transport (Borjesson et al., 2015).

Other than the above successfully implemented cases, several cities also tried to impose the congestion pricing policy but failed. Between 1983 and 1985, Hong Kong's experiment with electronic road pricing failed due to strong opposition from the public (Borins, 1988). In 2005 and 2008, a referendum on a Edinburgh congestion charge ended with a 74.4% rejection vote, and the same occurred in Manchester with a 78.8% rejection vote (May et al., 2010).

Chapter 4: Findings

This section demonstrates the findings based on the results of the literature search and classification process. Effectiveness of the existing cases are widely discussed in the last ten years. In this study, I summarize the data from the five implemented cases and conclusions from literature to figure out whether congestion pricing has successfully solved the congestion and environmental problems. Then, through the review process, I identify equity concerns and public acceptance being challenging obstacles of congestion pricing implementation. The debate of the equity issues that originated from distributional effects , the factors that impact on public acceptability and how to enhance it are detailed discussed in the section. The optimization of congestion pricing design in terms of applying user heterogeneity and exploring other alternative methods is analyzed as well. Last but not least, various secondary effects of congestion pricing are listed and accessed in this section.

4.1 Effectiveness

4.1.1 Transportation Effects

As shown in Table 4, congestion pricing works well for controlling traffic. As sown in Chapter 3, congestion can be largely relieved through decreased traffic volume, increased travel times reliability, or increased public transit ridership. This suggests that, as expected, a congestion charge can succeed in affecting traveler behavior on various decisions: whether to take a certain trip, which mode of transport to use, and when to travel.

Table 4. Congestion Pricing Schemes and Corresponding Impacts

	Singapore's ERP (successor to ALS 1975-1998)	**London LCC**	**Stockholm congestion charge**	**Milan Area C (successor to Ecopass 2008-2011)**	**Gothenburg congestion charge**
Inception	1998	2003	Trial: January - July, 2006 Permanent: 2007	Trial: 2008 - 2011. Permanent: 2012	Trial: 2013 Permanent: 2014
Type of schemes	Cordon scheme (mainly)	Zonal schemes	Cordon scheme	Cordon scheme	Cordon scheme
Charge area	Three cordons in the CBD and expressways	Original 21 km^2 area in city center, extended to west	Cordon around 30 km^2 inner city area	8 km^2 area in city center	A circle cordon with two expressways.
Supplementary measures	Parking fees, car ownership taxes, park-and-ride areas.	Promoting bus services	New bus lines, mass transit service improvement, park-and-ride facilities	New bus lanes, decrease on-street parking	New bus lanes, parking restrictions.
Congestion Reduction (traffic volume)	-44% car trips (ALS) -15% car trips (ERP)	-33% car trips	-22% across cordon, -16% within cordon	-14% car trips (Ecopass) -30% car trips (Area C)	-12% car trips
Congestion Reduction (other)	travel speed increased from 18-22 MPH to 24-28 MPH, bus ridership increased by 15%	-30% traffic delays, +38% bus ridership	-30%to - 50% traffic delays, +4%- 5% transit system usage	+4% travel speed,	few travel time savings
Emission reduction	-10% to - 15% CO_2 and other greenhouse gas emission	-16% CO^2, -15.5%PM10, -13.5% NOx	-14% CO^2, -9% PM10, -7% NOx	-18% PM10, -10% CO_2	has not been observed

Note: Leape, 2006; Phang & Toh, 2004; Anas & Lindsey, 2011; Beria, 2016; Borjesson & Kristoffersson, 2018; Lehe, 2019.

However, unlike the significant transportation impacts of the first adoption, charging increases often have much milder effects after the implementation. Most schemes raised their charge a few years after introduction, but there is no linear relationship between price increases and traffic reduction (Lehe, 2019). One possible explanation by Borjesson and Kristoffersson (2018) is that the initial introduction of a charge discourages drivers with elastic demands and these people are priced out in this process. Therefore, the remaining drivers who are subject to subsequent charge increase are those who are less price sensitive, and they wouldn't change their travel decisions. The lesson from this phenomenon is that the increase of charge prices would not be used to further solve the congestion problem.

One aspect that is highly influential to the schemes' performance of congestion alleviation and further transportation context is the exemption regulations (Lehe, 2019). Recently, the rise of app-based ride-hailing services has caused a big pressure on London's traffic in the congestion zone because for-hire vehicles are exempted from the charge. In Stockholm, the exemption of alternative fuel vehicles leads to an increase of ownership of this kind of vehicles shortly after the adoption (Borjesson & Kristoffersson, 2018). Therefore, the exemption regulations, which are flexible and easier to adjust, could be regarded as an efficient way to revise to achieve different goals.

4.1.2 Environmental Effects

The majority of prior research on urban traffic congestion pricing has focused on its role in reducing congestion. Recently, with the deteriorating urban environment caused by vehicle emission， attention has been largely turned to its effects on environmental protection. Using congestion pricing as an instrument to improve air quality and environment has been adopted in several cities. Milan's Ecopass system, which was aimed to reduce pollution in urban areas and charge the vehicles by their emission levels, is the prototype of Milan's Area C congestion pricing system. Area C still follows the previous regulations of exempting green vehicles and banning most high-emission vehicles. As shown in Table 4, most of the schemes considerably reduced vehicle emissions. Meanwhile, based on the experience of Stockholm and Gothenburg schemes, the potential environmental benefits played an important role in the referendum to win public support (Borjesson et al., 2016).

With the increasing attention to environmental pollution, the effect on emission reduction has become another advantage of congestion pricing. More cities realize that urban congestion pricing can be used to internalize the cost of emissions as well as the cost of congestion. Hence, the environmental benefits could be one appealing incentive to popularize the implementation of congestion pricing.

4.2 Obstacles: Equity Concern and Public Acceptance

The equity concerns regarding distributional effects and public acceptance of congestion pricing have been recognized as big threats that blocked the implementation for a long time. Within the last ten years, scholars continue to pay much attention to these two factors.

4.2.1 Equity concern

The equity concern of congestion pricing mainly comes from several arguments that congestion charges are more beneficial to high-income citizens because low-income groups are more likely to be priced off the road due to the low value of time (Arnott et al., 1994; Giuliano, 1992). This income-based distributional effect could be explained by the fact that high-income users are more inclined to remain on the highways because they can afford the congestion fee and benefit the convenience, but low-income users get worse off because they have to select less-expensive travel choices. However, other research shows that arguments typically come up in an American context where cars are the dominant mode of transport and travel patterns are similar between people from different income groups (Evans, 1992). Researchers also found that the distributional effects due to the differences in value of time (VOT) lead to public resistance to this policy (Verhoef & Small, 2004). Given this complicated situation about distributional effects of congestion pricing, many quantitative studies were carried out to investigate it. Abulibdeh (2018) and Takayama (2020) state that the effect of area-based congestion pricing would be regressive, which will help rich commuters but hurt poor commuters. Liu and Nie (2012), as well as Kristoffersson et al. (2017) conclude that a trade-off exists between efficiency and equity and argue that the policy would be less controversial if the revenues are spent to benefit low-income groups, such as supporting public transit.

Eliasson (2016) analyzes this issue from two different perspectives: consumers and citizens. The result of this study indicates that from a consumer perspective, high-income groups pay more than low-income groups, but low-income groups pay a greater percentage of their income which is consistent with prior equity assessments. However, from a citizen perspective, each one could be viewed as the winner as long as the purpose of the congestion policy aligns with individuals' societal. A more positive argument comes from the study of Beijing's potential scheme indicating that the congestion charge is politically progressive (Linn et al., 2016). Various instruments explored in recent literature could help alleviate this problem, such as using revenues to accurately facilitate the vulnerable group through complete equity evaluations using agent-based models (de Freitas et al., 2017).

Different conclusions may depend on the structure of the transport system, the spatial distribution of residents, and particular congestion-charging schemes. Since these characteristics differ significantly between cities and regions, the study concludes that equity must be assessed on a case-by-case basis.

4.2.2 Public Acceptance

Public acceptability has direct impacts on whether one congestion policy could be implemented under a democratic system. Proposals of Hong Kong, Edinburgh, and Manchester failed due to strong public opposition. As widely recognized as a significant barrier to widespread adoption, 22 articles pertain to this topic, making it the most popular topic in the past decade in this field of research.

Based on the valuable input from various scholars, four factors are commonly identified as key determinants: Privacy, Equity, Complexity, and Uncertainty (Gu et al., 2018; Selmoune et al., 2020; Zheng et al., 2014). This study refines the outcome by analyzing the latest research (see Table 5).

Table 5. Factors Influencing Public Acceptability

Factors	**Description**	**Supporting Literature**
Privacy	Invasion of personal privacy due to the recording of travel information.	(Emmerink et al., 1995; Z. Y. Liu et al., 2014; May, 1992; Parry, 2009; Schaller, 2010)
Fairness	Whether the proposed scheme could benefit the majority. Self-interest from an individual perspective.	(Eliasson, 2016; Giuliano, 1992; Hensher & Li, 2013; Jagers et al., 2017; Zheng et al., 2014)
Complexity	Whether the scheme or charge rule could be well-understood by the public.	(Hensher & Li, 2013; May, 1992; Rotaris et al., 2010; Schaller, 2010; Zheng et al., 2014)
Uncertainty	The familiarity of status quo and worries of effectiveness	(Eliasson & Jonsson, 2011; Hansla et al., 2017; Hensher & Li, 2013; Milenković et al., 2019)

Privacy invasion is the foremost reason that led to the rejection of Hong Kong's proposal (Hau, 1990). Further, acceptability will decrease when people feel the scheme would bring a loss of freedom and comfort due to travel patterns change (Schaller, 2010). These issues were proactively addressed in Singapore and London.

Self-interest would be the first incentive of an individual's decision on the referendum (Hårsman & Quigley, 2010). Thus, whether the proposed scheme could benefit the majority will influence the result of public acceptability. As discussed before, the debate of whether congestion pricing has distributional effects between high- and low-income people continues, and revenue allocation would be helpful to address the equity concern. Meanwhile, as one component of perceived fairness, the faith about the environmental effects that could help to protect future generations, weighs more than other factors (Borjesson et al., 2016). It implies the government authorities should address the equity concern and emphasize fairness when introducing it.

The rejection of Edinburgh and Manchester schemes is partly because of the complicated scheme design (Gu et al., 2018). The clear and concise scheme design promoted the public acceptability in London’s and Milan’s case (Hensher & Li, 2013; Rotaris et al., 2010). Thus, a simple and easy-understood proposal would help to gain positive opinions from the public.

Because people tend to remain inert about the status quo and resist changes (Hansla et al., 2017), perceived uncertainty could impede the adoption of the new policy. Both

Stockholm and Milan's experiences reveal the familiarity phenomenon (Hensher & Li, 2013). The worries of the proposal's effectiveness drive people to make more conservative decisions and resist congestion pricing (Milenković et al., 2019). Hence, the real experience of this system would increase public acceptability.

Henser and Li (2013) put up with a two-step approach to overcome the difficulty and gain support from the public, and this approach was supplemented with suggestions from Gu et al. (2018): 1) during the design process, fairness and complexity concerns should be addressed by active public propaganda; 2) a trial is highly recommended before the referendum or implementation, and the outcomes should be accessible to the public; and 3) governments are supposed to maintain the practice especially during the trial process to build up the social trust, such as making sure the revenue allocation as promised.

4.3 Congestion Pricing Scheme Optimization

From urban congestion pricing experience and the discussion about the equity concern and public acceptability, we learn that most cities are hesitant to adopt this effective but controversial policy. The distributional impacts on different income groups have always been a tricky problem that has not been solved yet. Based on the accumulated practical experience and in-depth theoretical analysis, congestion pricing optimization also raised intense discussion in the last ten years.

4.3.1 User Heterogeneity in Scheme Design

Drivers are often identified as a vulnerable group with congestion pricing when revenue reallocation fails to compensate them. This conclusion traces back to Walters' (1961) analysis of homogeneous drivers.

The distribution effects decided by travelers' value of time lead to inequity: Simply put, high-income people win and low-income people lose. In a broader context, the dimension of user heterogeneity is not only differentiated by the VOT (Zheng & Geroliminis, 2020) but also individuals' travel choices and spatial distribution(Takayama, 2020). User heterogeneity is identified as one important treatment of equity concern to optimize the design and elevation process (Heller et al., 2019; Zheng & Geroliminis, 2020).

Various studies aimed to identify to what extent and in which aspects that user heterogeneity influences congestion pricing. Percoco (2015) confirms users' heterogeneity impacted their reaction to congestion pricing policy through an empirical study in Milan. Liu (2012) highlights the spatial heterogeneity of the distributional effect. This article showed that low VOT users tend to benefit more from greater coverage of transit services. Under poor transit coverage, travelers who have limited access to transit services suffer the most severe differential effects. Börjesson (2014) demonstrates including user heterogeneity regarding different VOT and travel behaviors in the scheme design process could prompt the benefits of congestion charges (Börjesson & Kristoffersson, 2014). Zheng and Geroliminis (2020) conclude there is a significant impact because of the heterogeneity in travel behavior and has a direct relationship with the welfare of congestion pricing. De Freitas and colleagues (2017) show that agent-based simulations with heterogeneous values of time would help to make equity evaluations of certain pricing schemes. All these studies identified user heterogeneity, especially value of time, as an important factor in making optimal congestion pricing schemes and improving equity issues. Meanwhile, three models that could simulate user heterogeneity are built for future studies (Heller et al., 2019; Sabounchi et al., 2014; Zheng et al., 2012). User heterogeneity, which is repeatedly verified in the last ten years, impacts not only on equity but also on the welfare of the system. It is also identified as one of essential factors to optimize the scheme design.

4.3.2 Congestion Pricing vs. Tradable Credit

Tradable credits, an innovative concept in the congestion management field, was put forward by Yang and Wang (2011). This scheme freely distributes certain credits to travelers for traveling on the road network. Additional demand for more credits enabling the right to travel is then to be traded between users in the market base. The government would act as the manager to monitor the system rather than interfere with the trading market. This system is revenue-neutral since the money circulates within the user group. The most attractive selling point of this scheme is described as "effective yet equitable"

(Wu et al., 2012) because it addresses the equity concerns by appropriate credit distribution among travelers.

Although this concept has the theoretical advantage, competing arguments occurred in literature (see Table 6). Shirmohammadi et al. (2013) compare the congestion pricing and tradable credits schemes' performance under uncertain transportation supply and demand. Contrary to congestion pricing, the result reveals that tradable credit schemes succeed in controlling network mobility but leave the credit price volatile (Shirmohammadi et al., 2013). After a comprehensive review of comparative analysis between tradable credits and congestion pricing, Fan and Jiang (2013) came to a more negative conclusion that there is no superiority between these two concepts, and it may depend on further schemes design of tradable credits. Later, Krabbenborg and co-workers verified the public acceptability through qualitative (Krabbenborg et al., 2020) and quantitative studies (Krabbenborg et al., 2021). All of the results reveal there is no considerable public perception of tradable credit schemes, and technical feasibility, political acceptance, and the societal benefits are vital factors to make this concept applicable (Fan & Jiang, 2013, Krabbenborg et al., 2021). According to the discussion in the last ten years, competing attitudes have occurred alongside experiments. These results reveal lots of difficulties and attitudes towards this alternative method changing from positive to negative. This promising concept is still in the initial stage and deserves more empirical studies to examine its advantages in the future.

Table 6. Core Literature on the Tradable Credits Scheme

Literature	**Content**	**Conclusion**	**Implication**
Shirmohammadi at el (2013)	Explore the different performance of congestion pricing and tradable credits schemes under uncertain transportation supply and demand.	Congestion pricing fixes the price but fails to achieve the control target. In contrast, tradable credit schemes ensure that the control aim is met while leaving credit prices fluctuating.	sensitivity analysis should be conducted to predict price fluctuation.
Fan and Jiang (2013)	Review and compare a variety of tradable mobility permits schemes and congestion pricing schemes.	No general superiority between the tradable mobility permits schemes and the congestion pricing. Different tradable credit schemes are applicable for different contexts.	Tradable credits are still a concept rather than a developed policy that can lead to different scheme design
Krabbenborg at el. (2020)	Explore the public acceptability of tradable credit schemes among 36 Dutch citizens.	Participants revealed a skeptical attitude towards TPC or were more convinced about PC	More research should be conducted to explore public acceptability.
Krabbenborg at el. (2021a)	Analyze feasibility and interview experts in this field.	Insurmountable barriers and challenges in the social and political context	Tradable credit concept is unable to compete with more established charging schemes
Krabbenborg at .el (2021b)	Explore the public acceptability of tradable peak credit by a stated choice experiment.	Between 32% and 52% of the public supports tradable peak credits (TPC). Higher support from people regards it as fair and effective.	The tradable credit schemes should also be technically feasible, politically acceptable, and the societal benefits to be applicable.

Another replaceable instrument to congestion management is rewarding strategies, which usually refer to peak avoidance rewards. Comparing the public opposition to excessive travel costs, providing monetary incentive in rush hours would be more acceptable to travelers. The effectiveness of rewarding strategies is examined by the studies of Netherlands (Tillema et al., 2013) and Beijing (Li et al., 2019). The former research gained a positive conclusion that rewarding is more effective in diverting commuters from peak periods than congestion pricing. The latter showed the effectiveness of this scheme is significantly different between more and less habitual automobile travelers. That reward strategies are more effective than congestion pricing in promoting mode shifts among less automatic habitual travelers. But this strategy faces challenging political acceptability as the government needs to offer subsidies (Zheng et al., 2020).

4.4 Neglected Area: Secondary Effects

As an important traffic demand management method, Congestion pricing has received considerable interest in various dimensions, such as traffic efficiency, environment improvement, and equity concern. All these discussions in literature drive it to be more optimal and attractive to policymakers and the public. Nevertheless, McArthur (2012) and Brown (2015) both argued that one area which has received less attention is the secondary impacts, either positive or negative (Brown et al., 2015; McArthur et al., 2012). Various secondary effects are identified but received insufficient attention or remain hazy because of competing conclusions (see Table 7).

Table 7. Secondary Effects of Congestion Pricing

Secondary Effect	**Literature**	**Conclusions**
Real Estate	(Glen & Nellis, 2011)	House prices within the congestion charge zone in London decreased temporarily after the introduction but gradually returned to the pre-charge level in 2007.
	(Percoco, 2014)	Housing prices in the charge area decreased in Milan.
	(Agarwal et al., 2015)	Toll increase has no impact on office and residential real estate, but retail real estate prices dropped 19% within the cordon.
	(Tang, 2021)	Congestion Charge increased house value and generated €3.8 billion for homeowners in the zone.
Local Business	(McArthur et al., 2012)	Congestion Charge could cause unemployment disparity.
Public Health	(Brown et al., 2015)	Potential physical activity effects of congestion pricing are weak.
	(Verma et al., 2015)	Congestion Pricing could lead to a sustainable travel pattern.

4.4.1 Real Estate

The most hotly debated secondary effect is the impact of real estate prices. There are two competing opinions about the potential effects: local policy makers argued the improvements in environmental amenity, related to increased journey speeds of all transports modes, fewer accidents, and improved air condition would be capitalized into increased local residential property values, while their opponents refuted that the high motoring cost would be detrimental to local residents, which would depress the local housing prices (Glen & Nellis, 2011). Glen (2011) applied house purchase transaction data from 1999 to 2007 and compared the trend of average housing prices inside and outside the zone. The result shows that the prices within the congestion charge zone in London decreased temporarily after the introduction but gradually returned to the pre-charge level in 2007. Percoco(2014) concluded that housing prices in the cordon decreased in Milan. However, Tang (2021) refutes that traffic improvement capitalized €3.8 billion in housing using the housing transaction from 2000 to 2010. Agarwal (2015) identifies different types of real estate and finds that office and residential real estate in Singapore have little effect from the increased charge. Still, retail real estate prices dropped 19% within the cordon area.

4.4.2 Local Business

Congestion pricing has a wide effect on local businesses, including commercial activity, businesses in the areas, and changes in the level of local employment (Glen & Nellis, 2011). McArthur (2012) demonstrates that introducing a congestion charge causes unemployment disparities between the charged zone and other areas. The discussion of real estate impact also applicable to this topic in terms of whether congestion pricing promotes local business by capitalizing the benefits or impedes it because the travel cost may expel potential customers. There were research before 2010 that tried to explore this question by using London as the case (e.g. Quddus et al., 2005, Quddus et al., 2007). But they all had trouble in separating data of the congestion charge zone from central London which leads to the unreliable outcomes.

4.4.3 Public Health

Transport behaviors play an important role in health because travel modes directly influence an individual's physical activities. Congestion pricing, an effective method to adjust transport behaviors sustainably, could also benefit health by increasing physical activities. Brown et al. (2015) demonstrates that although their study finds the relationship between congestion charge and public health is weak, transport policy such as congestion pricing could promote public health.

Like many scholars' arguments, this study finds that secondary effects are less explored in the literature. The impact of housing prices is necessary to be identified because it could generate a significant potential impact on public acceptability, and residents have the right to know it. Although the impacts on local business are recognized as an important secondary effect, it did not win much attention recently. More research is suggested to optimize congestion pricing policy to compensate if it undermines the value or wins public acceptability if it capitalizes the benefits. As for the potential activity benefits generated from travel modes shift to more active transportation, such as bicycling or walking, it would be advantageous to publicize congestion pricing policy if examined properly. Only with better understanding and full recognition of the potential health impact can congestion pricing be fully utilized as a beneficial instrument not only in traffic reduction and health promotion.

Chapter 5: Three Recent Cases

In this section, I outline two congestion pricing cases (Milan and Gothenburg) implemented in the last ten years and one in-progress scheme (New York), reporting on each system's implementation, design, transportation impacts and related issues. Discussions and implications are based on the findings of the literature review and the practical experience in the last ten years.

5.1 Milan

Milan is one of the large cities that suffer from air pollution in Europe (Danielis et al., 2011). Milan's congestion pricing system has a very close relationship with its emission charge zone "Ecopass" in the central area of Milan. Because of worsening pollution and European Union's emission limits (Beria, 2016; Percoco, 2015), the city launched "Ecopass" in 2008. The Ecopass Area charges particular vehicles by its emission class that is assessed by a complex charging structure. The trial period lasted until 2011 and won positive results: 79% of voters approved the introduction. The vote gave the essential political legitimacy for the existing program to be evolved into a new, more efficient, congestion charge plan. In 2012, the pricing system evolved into the congestion pricing system, named Area C, with the same area and technological infrastructure.
Area C encompasses the Cerchia dei Bastioni (C.B.), an 8km² area delimited by the 16th-century wall. It is a cordon scheme that consists of 43 access control points, shown in Fig.6. Although it still keeps the daily-charged method, the structure of pricing changed as the system transferred from Ecopass to Area C. Same with London Congestion Charge, charges are flat and charge once per day. Ecopass pricing the charge by the engine's level of emission ranging from 0 to 12.19$(2021 rate), while Area C divides users into three categories: resident, service vehicle and standard. Resident vehicles have the least charge, and service vehicles which are associated with commercial activities have certain discount as well. Residents who live inside the zone enjoy 40 free entrances per year and have the discounted price for extra entrances (Beria, 2016). All the revenues from this policy are embarked to promote public transportation and sustainable mobility.

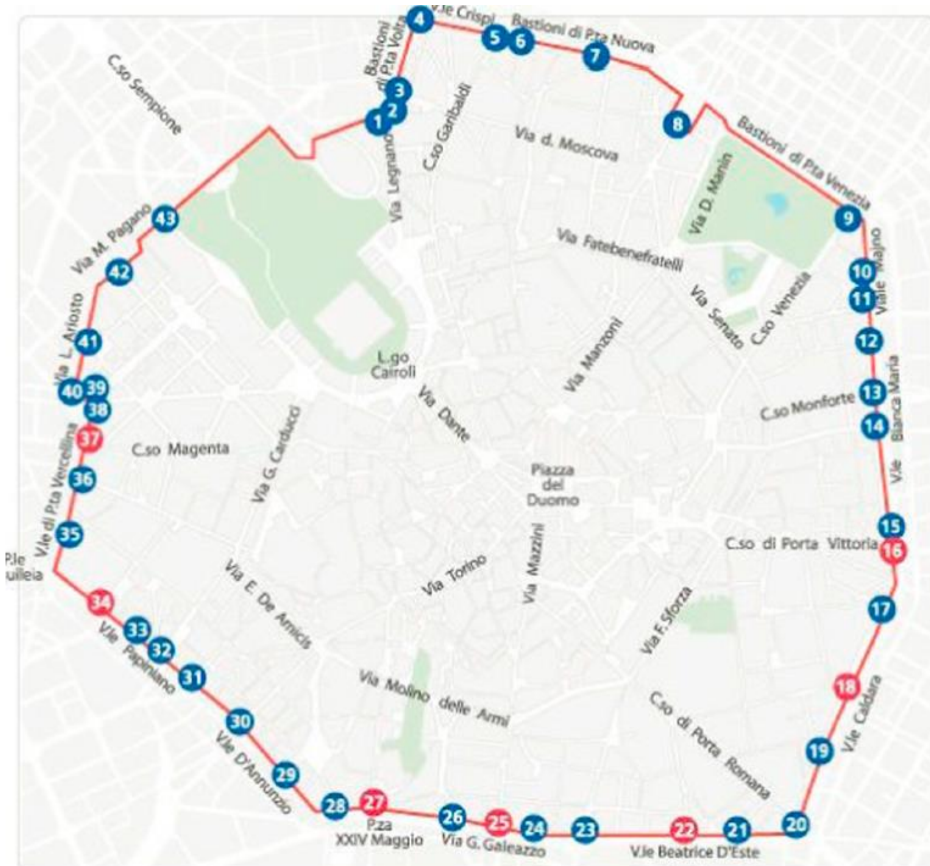

Figure 6. Milan Area C

Note: Lehe, 2019.

Comparing to other cases, the high approval rate for congestion pricing plan is one unique feature of Milan Area C. According to the factors that influence public acceptability that discussed in chapter 4, there are several reasons could explain it. First of all, the scheme design well addressed the distributional effects so that the perceived fairness was greatly enhanced. The appropriate pricing discounts and partial exemptions for the most affected users, such as commercial vehicles and residents, contribute to gaining their support. One study analyzes the spatial distribution of the referendum results and finds that the maximum of acceptability is inside the cordon (Boggio & Beria, 2019). Another study indicates responses to pricing vary with transit availability and points out welfare impacts from pricing are spatially heterogeneous (Gibson & Carnovale, 2015). These could explain the necessity of taking user heterogeneity into account in the scheme design process.

Meanwhile, as the Area C system transformed from the Ecopass, the uncertainty concern gets lessoned because citizens has already familiar with a similar policy. Additionally, the emphasis on environmental effects of this system also lead to widely acceptability due to the faith about the potential environmental benefits.

5.2 Gothenburg

on January 1, 2013, Gothenburg, Sweden’s second-largest city, adopted a time-of-day dependent cordon-based congestion charging plan. The system consists of a cordon ring that covers the inner city of Gothenburg (Figure 7). In many aspects, Gothenburg congestion charge scheme resembles the scheme operated in Sweden's largest city, Stockholm. They both utilize the same technology and scheme design (Danielis et al., 2011): tolls imposed on drivers crossing in both directions of the control points and varied pricing depending on the time of the day and recognized by the cameras on the top of the gantries. Charges are levied 6:30-18:30 on weekdays with a maximum of 2.65$ (as of 2021). One of the unique features of this scheme is that the vehicle only pays the highest possible charge even if it crosses various control points within 60 minutes, which is called the "single-charged" or "multi-passage" rule (Gothenburg; Statutes).

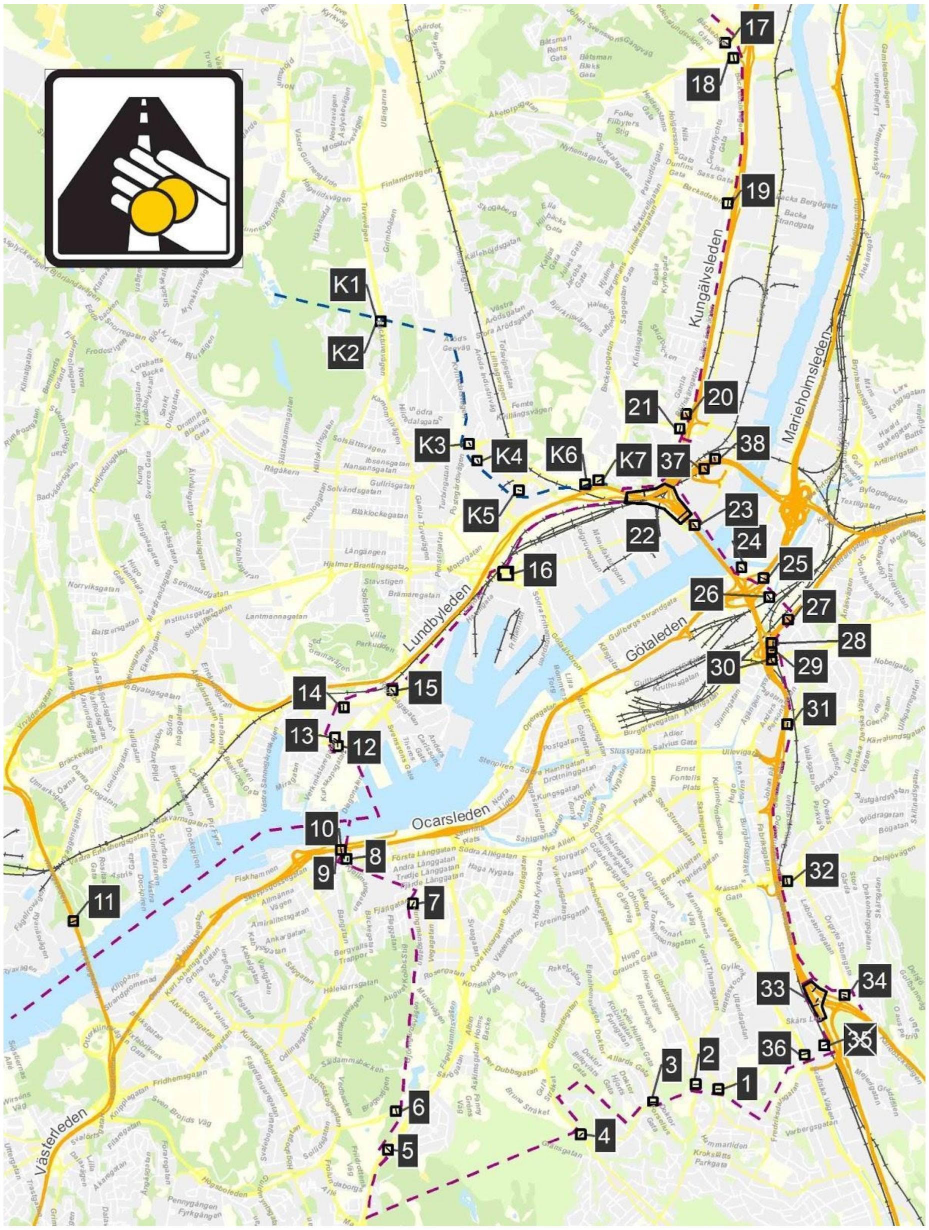

Figure 7. Gothenburg Congestion Pricing

Note: Lehe, 2019.

Inspired by Stockholm's congestion pricing practice, the City of Gothenburg proposed the congestion pricing tax to co-funding a large infrastructure package (Borjesson et al., 2015). Besides, the secondary goal is to alleviate congestion as much as possible. The city council also promised to use the rest of the revenue to develop sustainable travel modes and improve the local environment (Hansla et al., 2017). Although there has been an improvement in public support after the trial, the referendum revealed that 57% of people still reject the tax, and Gothenburg's city council insisted on implementing it.

Same with other congestion pricing practices, such as London, traffic volume decreased sharply right after the implementation of the congestion charge and bounced back and stabilized at 12% reduction after 8 months. Also, there is no significant charge after the toll increase in 2016 motivated by raising revenue. The traffic condition within the inner city has also been improved thanks to other traffic demand management methods, such as promoting the public transit system and related parking policy (Borjesson et al., 2015). Research indicates that traffic reduction results from switching travel modes to public transit, reducing travel frequency or changing destinations (Borjesson & Kristoffersson, 2015).

Gothenburg Congestion Pricing practice receive more critical comments than Stockholm in spite of many similarities between these two schemes. One aspect that has been criticized is that the local government was too eager to implement it with the purpose of gaining the federal funds for transportation infrastructure without considering the local condition. Gothenburg has less population and the congestion was not severe but mainly occurred on the highways near city center and travel time only take nearly 5 minutes (Börjesson & Kristoffersson, 2015). Due to lack of in-depth research and detailed scheme design, the reduction of congestion is much smaller than Stockholm and cannot reach the expected amount. The lesson from this practice is that policy makers should carefully evaluate local congestion condition and apply appropriate transportation demand management methods that are suitable for their own feature. Especially for several small cities, parking pricing could be more proper. Although congestion pricing is recognized as an effective method, detailed analysis and evaluation are necessary before the implementation.

5.3 New York City

Same as other cases mentioned above, NYC's congestion pricing plan has been discussed for many years. It was first introduced in 2007, together with New York City Mayor Bloomberg's comprehensive sustainability plan, and aroused heated debate at that time

(Schaller, 2010). The primary purpose of the congestion pricing plan is to alleviate the congestion, encourage public transit, and reduce air pollution. Although the result of a poll showed that the public had positive attitudes towards the policy as long as the revenue would be embarked on the improvement of the mass transit (Schaller, 2010), the proposal finally failed to win support from the New York State Assembly. Two main concerns were: potential equity issues caused by the toll offsets and imperfect public transit system could influence the accessibility once the charge is implemented (Baghestani et al., 2020). Ten years later, in 2017, the transit crisis due to the reliability and crowing and heavy traffic congestion posed a threat to residents' daily commuting (Yu et al., 2019). Congestion pricing plan was put up again to combat this situation by the State's governor, and the revenue would be used mainly for transit improvements in his proposal. Unlike the situation in 2007, when there existed disparities between the state government and the city, Cuomo (the States' governor) and de Blasio (the city's mayor) reached an agreement after negotiation and approved this plan in 2019. This made New York City the first city to enact congestion pricing in the United States. However, the block was from the federal government this time. As some federal roads were covered by the charge, the implementation required the approval of the Federal Highway Administration (FHWA). According to the National Environmental Policy Act (NEPA), the Metropolitan Transportation Authority (MTA) of New York must complete an environmental assessment (EA) or environmental impact assessment (EIS). Yet, the Federal Highway Administration (FHWA) didn't give clear directions or guidance for this review. The turning point of things is on April 8, 2021, when the Biden Administration activated the environmental assessment period to explore the potential reduction of traffic and air pollution and increase of transit usage.

This study identifies the equity concerns as an essential issue to deal with in New York's congestion pricing practice because it weighs a lot in this political setting and the complexity of population composition and distribution in New York City will aggravate this concern. User heterogeneities, consisting of various VOT, transit availability, and spatial distribution, are supposed to be carefully addressed in the scheme design process to avoid negative distributional effects. The revenue could be distributed to the vulnerable group in this plan.

Although most current research (Hårsman & Quigley, 2010; Börjesson et al., 2012; Gu et al., 2018) identified public acceptance as the most decisive factor of the implementation, based on New York's tortuous approval process, this study concluded that political support is another factor which could promote the congestion pricing implementation. In London, the mayor directly implemented this policy without the referendum. The Gothenburg case demonstrates that strong political support contributed to the successful implementation even though the referendum failed to win the support from the majority. However, according to New York City's experience, even though the result of a public poll revealed supportive opinions from the public, the plan still failed because of political resistance in 2007. Political support, which is influenced by various factors such as the institutional setting, has considerable impacts on the process of implementation in congestion pricing.

Chapter 6: Discussion and Conclusion

6.1 Discussion

Based on the existing case, this review found there exists direct influence between cases within similar context and background. The introduction of Singapore's ALS inspired a 21-month pilot, from 1983 to 1985, of Hong Kong's EPR (Hau, 1990). These two cities have similar topography and population and both experienced giant economic development at that time. London Congestion Charge also encouraged the attempts of Edinburgh and Manchester. What's more, Gothenburg's scheme was directly inspired from the Stockholm scheme with the same scheme design and same goals of raising revenues. The practical experience indicates the frequently discussed atmosphere of congestion pricing, and similarity within the public could contribute to the transferability between cities. Thereby. It indicates that the implementation of one particular scheme could be performed as a catalyst for wilder prospects.

Since it was proposed, congestion pricing has been one hotly debated and controversial topic either in theory or practice. Although the effectiveness of congestion reduction and environmental protection has been proved and confirmed by the existing cases, two main obstacles, the equity concern and resistance from the public, restrict its widespread implementation from different aspects. Also, it has been criticized for the potential secondary effects, such as the effects of real estate and local business. The real-world application of three recent cases also reflects the complexity of its implementation. In the past ten years, many scholars have dedicated to improving and optimizing this policy. This theory, with its theoretical advantages, has been continuously enhanced with the increase of cases and studies. Through literature review and the three case studies, I conclude congestion pricing would be an effective method to alleviate urban congestion and emission and it could be adopted in more cities if it is detailed designed based on the specific conditions.

Unlike its popularity in European cities, congestion pricing is rarely practiced in cities in developing countries and in the United States. Rapid urban growth, extreme population agglomeration, and underdeveloped infrastructure lead to the congestion problem becoming increasingly severe to cities in developing countries. Traffic delays and air pollution caused by congestion largely impact the economic development and the welfare of local residents. Although there has been no case occurring in developing countries from the literature, we can see that several cities discussed this policy, such as Beijing and Jakarta. Through this review, I identify several imperative factors in developing countries' congestion pricing development. First of all, public and political acceptance may be more challenging for cities in developing countries. According to Gothenburg's experience, existing successful congestion practices and social discussion promote public support (Borjesson et al., 2016). Meanwhile, awareness of environmental protection and general environmental attitudes also contributes to acceptability towards congestion pricing (Eliasson & Jonsson, 2011; Hensher & Li, 2013). Lack of experience and disparity in environmental attitudes will aggravate the people's skepticism towards congestion pricing. What's more, political acceptance could be another obstacle. Substantial financial investment, technological difficulties, and complex management issues could impede the support from policymakers (Sorensen et al., 2014). Also, how to legitimate congestion pricing remains difficult in particular political settings. Based on the findings from this study, I suggest extensive public outreach and education, in which educating and informing road users of the benefits and easing the uncertainty over effectiveness and equity, would be helpful to attract the attention and gain complete acknowledgment for congestion pricing. Meanwhile, to transfer the experience from developed countries, the differences in the transportation system and political settings must be fully considered. More studies and discussions under the context of developing countries are needed to facilitate the development.

This study also identifies several obstacles and suggestions in terms of the adoption of area-based urban congestion plans in American cities. First, the political settings make the approval of congestion pricing plans harder. In London, the mayor had the authority to implement this policy without any legislative approvals. Gothenburg's congestion pricing plan was conducted even without the support from the majority. These situations could hardly exist in the US. In New York City, for example, the congestion pricing plan needs both support from the city and State authority. What’s more, political acceptability of congestion pricing in Europe is better than in the US because of the experiences in other cities and the discussion atmosphere in academia, which could be demonstrated in

Chapters 4. Secondly, the difference in urban and transportation context could threaten the effectiveness of area-based congestion pricing plans. Unlike the dense and mixed-used cities in Europe, urban sprawl is one common problem in American cities. This leads to an auto-dependent lifestyle and less-developed transit systems, which will result in severe equity problems if an area-based plan is adopted. Here I also bring up some suggestions regarding the congestion pricing development in American cities. Firstly, congestion pricing would be more effective and applicable to the public if packaged with other traffic demand management methods, such as improving public transport services. Secondly, as most people still think it is another form of tax rather than a method that could directly benefit drivers (Schaller, 2010), this policy needs to emphasize the direct benefits to the drivers as well as the benefits to the whole society through public education and outreach. Because New York's congestion pricing plan made a breakthrough this year, more discussion in society and academia would greatly improve the acceptability of this concept in many American cities. Although many scholars argue that the prospects for broad implementation in the USA remain uncertain, I assume that New York's congestion pricing, if implemented successfully, will be a turning point to rethink this question.

6.2 Conclusion

As traffic congestion has become an increasingly serious problem in cities around the world, congestion pricing can solve the traffic externalities of congested traffic. This thesis reviewed the literature of the last ten years on this topic and identified three themes, which were revealed through the literature classification and analysis of 138 studies. The effectiveness of congestion pricing, including traffic effects and environmental effects, is one area being frequently discussed. Based on the result of these studies, congestion pricing not only largely reduces congestion but also benefits the environment through emission reduction. What's more, contributions to environmental protection are increasingly valued. The equity concern and public acceptability, regarded as the obstacles of congestion pricing implementation, are then detailed reviewed. Equity concern mainly derives from the arguments of distributional effects regarding users' different VOT, but the only agreement among various studies might be that it's more appropriate to assess it on a case-by-case basis. Many studies dedicated to figuring out factors that influence public acceptability, this review identifies four factors that are well-recognized through them: privacy, fairness, complexity, and uncertainty. Two major aspects related to scheme optimization are discussed in this study. User heterogeneity is identified as an important factor in making optimal congestion pricing schemes and improving equity issues. One innovative alternative method, the theory of tradable credits, was put up in 2011 and drew heated debate in academics. Through tests and verifications from both theoretical and empirical studies, it was proved to have no advantages over congestion pricing and still needs further improvements in terms of practical application. As for the review of secondary effects studies covering the topics of impacts on real estate, local businesses, and public health, this study found no concrete and reliable conclusions for each topic. It is recognized as one neglected area that requires more attention in the future.

Then, this study discussed three recent cases which are influential in the last ten years: Milan Area C, Gothenburg congestion tax, and New York City congestion pricing plan. Milan's case won considerably public support in the referendum because this scheme largely addressed the distributional effects to ensure fairness. The criticism of Gothenburg congestion tax is mainly due to its being driven by political power to gain revenue and its ignorance of scheme transferability between cities. New York's congestion pricing plan indicates that political support is one determining factor of congestion pricing implementation, which is as important as public acceptability. What's more, this study finds the implementation of one particular scheme could be performed as a catalyst for wilder prospects and discusses the prospects of congestion pricing in developing countries and American cities, which demonstrates it remains difficult for cities to introduce this system due to the disparities in political settings, public acceptability, and transportation context.

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